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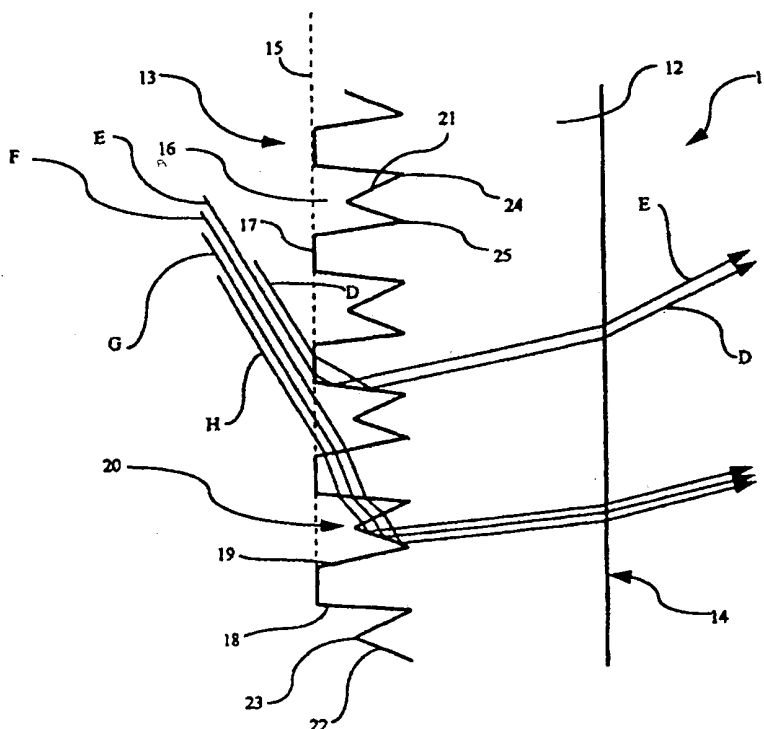
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(54) Title: A LIGHT-DIVERTING OPTICAL ELEMENT

(57) Abstract

An optical element (12) has two opposite major faces (13, 14), a first (13) of which, intended to be an incident face in use, is formed with a plurality of cavities (16) which extend partway through the thickness of the body (12) of the element. Flat faces (17, 32) formed either between adjacent cavities (16) or as the bottoms of the cavities, lie parallel to the opposite major face (14) of the elements so that light incident on these surfaces, and within certain range of angles, passes through the elements substantially undeviated to provide a view to an observer. Light entering the cavities (16) is refracted and reflected so as to be diverted into a narrower range of exit angles than incident angles thereby concentrating the light. In use as "daylighting" glazing transmitted light can be concentrated in an upward direction increasing the level of illumination within a room.



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## A LIGHT-DIVERTING OPTICAL ELEMENT

The present invention relates generally to a light-diverting optical element. Embodiments of the invention  
5 may be suitable for use in enhancing the internal illumination of buildings using daylight. Other embodiments may be used as light-diverting covers for light sources. Hereinafter, without prejudice to the generality of the invention, it will be described  
10 primarily in relation to its application as a glazing element.

Traditional glazing of openings in buildings allows the light from outside the building to enter substantially  
15 undeviated. Any bright areas in the external environment, therefore, for example the disc of the sun or the higher parts of the sky, give rise to concentrations of illumination within the rooms into which the light passes through the openings.

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In certain circumstances the intensity of the incident illumination in a room from a low angle, for example when the sun is low, can give rise to glare and even dazzling of the room's occupants when looking through an opening,  
25 such as a window, or even when just facing towards the window. This can be uncomfortable, inconvenient or even distressing unless some form of shading is available. Because the incident light on the exterior of a building

is for much of the time generally brighter and more intense at higher angles of elevation, the majority of the incident light usually enters the room travelling downwards towards the floor. It has long been appreciated that by providing light-diverting optical components as part of the glazing across openings in buildings it is possible to cause the incident light to change direction and be diverted into the room in a direction towards the back wall or ceiling thereby improving the illumination within the room for a given level of external illumination. Early attempts at such "daylighting" illumination involved the use of prismatic elements and were impracticable for a number of reasons, not least because the light transmitted therethrough was diffused and therefore allowed no view of the outside.

This arises because, the light diversion caused by such elements allowed for no undeviated light transmission. However, the occupants of buildings do not merely require the internal environment to be illuminated, but in general need, or at least prefer, to be able to observe the outside world through the windows. In order to achieve this at least some of the light passing through the windows must, therefore, be substantially undeviated. However, in many prior art "daylighting" systems substantially all the light is deviated either by refraction or reflection to such an extent that any image of the external environment is so diffused as to be

indecipherable. The occupants of rooms having windows glazed with such elements would have had no view outside.

Another more recent system is discussed in International Patent Application WO 91/03682. This describes a stacked array of refractors defining an illuminating channel between opposite surfaces of each element of the array. The elements have parallel faces by which adjacent elements are secured together using adhesive. Light entering an incident surface of an element at a relatively low angle of incidence is refracted to an interface and from there reflected to an emergent face through a channel defined in the element. The ratio of undeviated to deviated light is extremely low and the view of the outside world through a window glazed with such a system is still very poor. In GB Patent 2 240 576 an element having narrow slots in an exit face is described. The manufacturing techniques necessary to make such narrow slots make this configuration prohibitively expensive.

The applicant's own earlier International Application PCT/GB 94/00949 also describes an optical component suitable for use in "daylighting" buildings. This comprises two substantially planar elements each having a plurality of elementary surfaces formed on one face, respectively an inner and an outer face of a cell formed by the two elements. The elementary surfaces are

effectively defined by grooves formed on the face of each element, and the elements may be supported on a substrate such as a flat glass panel or may be secured together so as to be self-supporting. The use of two matched  
5 elements, adhered together, produces an extremely effective daylighting element, but at some cost disadvantage due at least in part to the need for two elements. This system does however offer an outside view by allowing a proportion of the incident light to be  
10 transmitted through undeviated.

The present invention seeks to provide a single element which can act both to allow light within a range of incident angles close to the normal to a general plane of  
15 the element to pass through the element substantially undeviated (thereby providing a view through the element) whilst light incident at greater angles of elevation (namely from higher in the sky) is deviated.

20 According to the present invention, therefore, there is provided an optical element comprising a transparent body having two substantially parallel major faces one of which is interrupted with a plurality of cavities defining a plurality of interfaces at which light  
25 incident thereon over a certain range of angles is reflected by total internal reflection, characterised in that at least some of the light incident on the said body is substantially undeviated in its transmission through

the body, in that the said one face of the element in which the cavities are formed is intended in use to face a source of light, and in that the width of the cavities is such that at least a substantial proportion of the light incident on the said one face enters the said cavities.

The present invention has the advantage that, because light entering the cavities is "useful" light in that it is transmitted through the element in desired directions, the cavities can be relatively wide in relation to their depth (in particular, of the same order of magnitude) thereby facilitating its manufacture.

It is of great interest in "daylighting" buildings, to be able to divert light incident at a steep angle to the horizontal, that is from high in the sky, away from its downward path, preferably to an upward path so that this light, upon entering the building, is directed towards the ceiling or an upper part of a back wall of a room. At the same time it is desirable to avoid glare from high intensity light incident from a low angle which may arrive directly at the eyes of an observer.

It is also of interest to be able to vary the behaviour of incident light at different angles of elevation. For this reason, in embodiments of the invention the said cavities are preferably formed as elongate grooves in the

said first surface of the element. Such grooves are preferably orientated horizontally so that the angle of elevation is changed as light travels through the element, whereas the direction of incidence is relatively less influential.

Alternatively, however, the cavities may be formed as pits or depressions so that both the angle of elevation and the direction of incidence both influence the diversion of the light as it passes through the element. For example, if the element were used as a cover for a light source this would allow light emanating from the light source to be diverted in selected directions as well as elevations.

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In embodiments of the invention formed with parallel grooves constituting the said cavities these may be defined by at least two side walls and the maximum groove width, namely the maximum separation between the groove walls, is preferably not less than the separation between adjacent grooves. This allows relatively wide grooves to be formed, simplifying the manufacturing process.

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The said substantially laminar element may be a unitary element of flexible material adapted to be supported on a face of a substantially planar support element. In such an embodiment the element may be made, for example, from a transparent plastics material which is not self-

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supporting. It may for example be made as a relatively thin film suitable for attachment to the internal surface of a flat pane of glass. The attachment may be achieved by filling the cavities with a suitable transparent  
5 adhesive which constitutes the said surrounding medium, or the attachment may be made by adhesive applied only between the contacting surfaces of the body and the planar support element, in which case the said surrounding medium may be air or other gas filling the  
10 cavities. An element may alternatively be supported at its exit face on the front face of a support such as a flat pane of glass, typically the "inner" pane of a double glazing cell.

15 Other production techniques, may be employed, however, either to form the body as a substantially rigid self-supporting component, or as a plurality of juxtaposed or connected elementary parts, conveniently in the form of elongate strips stacked with interfaces substantially  
20 transverse major surfaces defined by assembled elements.

Regardless of whether the cavities are formed as individual pits or elongate grooves, each cavity may be defined by surface elements which may be flat or curved.  
25 Preferably, at least some of the cavities have at least one wall composed of at least two substantially planar wall elements inclined at a non-zero angle to one another. Individual pits may be formed as short grooves

with longitudinally adjacent grooves being offset or staggered in relation to one another.

If the cavities are formed as elongate grooves in the said first surface of the element at least some of them may have a groove bottom constituted by the intersection of the groove side wall elements, or by the intersection of a groove side wall element with a groove side wall. In other words, the groove may be substantially V-shape and although, because each groove is defined by three wall elements, only one may be a substantially planar wall, the bottom of the groove is effectively a line defined by the intersection of two faces. These faces may be plane faces or curved faces and the curvature may be convex or concave.

In an alternative embodiment, however, at least some of the elongate grooves in the incident surface of the body may have a substantially flat bottom wall. In such embodiments the separation between adjacent grooves may be reduced to zero so that the incident surface of the body is constituted in effect by a plurality of lines defined by the intersection of the side walls of adjacent grooves. In such an embodiment the adjacent grooves are effectively contiguous.

In a further embodiment of the invention at least some of the elongate grooves in the said body have a bottom wall

defined by two surfaces inclined to one another at a reflex angle. This form of groove has particular advantages in allowing a greater width without loss of diverted light since the two surfaces of the bottom wall  
5 inclined to one another at a reflex angle can be considered to constitute a small triangular prism at the bottom of the groove, which further diverts incident light by refraction and reflection as will be described in more detail hereinbelow.

10

In another aspect the present invention provides an optical element for transmitting light incident over a range of angles and having a plurality of elementary surfaces which result in refraction and/or reflection of  
15 the incident light, in which the said elementary surfaces are inclined to one another in groups such that light incident on the element over a first range of incident angles is transmitted therethrough with at least a majority of the light being transmitted within a second  
20 range of exit angles, the second range being narrower than the first. Embodiments of the invention may be so formed that the groups of elementary surfaces are elongate facets defining the faces of a plurality of generally parallel grooves in at least one face of the  
25 element.

A further aspect of the invention provides a transparent optical element having a plurality of elementary surfaces

so arranged that incident light, at least to one side of a normal to the incident surface, at less than a certain threshold angle is reflected at an interface of the element with the surrounding medium, and light incident at angles above the said certain threshold is refracted at the said interface such as to be deflected into incidence with a next adjacent elementary surface at an angle less than the said certain threshold. Embodiments of the invention may be formed so that a plurality of the elementary surfaces together define a plurality of said threshold angles of incidence at each of which a proportion of the refracted light is deflected so as to be below the threshold angle for the next adjacent surface element in the path of the incident light.

15 Likewise the elementary surfaces may be formed as elongate facets defining a plurality of substantially parallel grooves in the incident surface of the component, which extend generally horizontally when the component is in its intended position of use, and those facets defining the generally downwardly facing surfaces of the grooves are inclined to one another at shallow angles such that each said downwardly facing groove-defining surface is downwardly convex.

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25 In such an embodiment the acute angle at which the said two bottom wall surfaces meet is preferably greater than the angle between the two groove walls or the wall surface elements adjacent to the groove bottom.

Although the above discussion makes specific reference to the use for daylighting buildings, the present invention may also find utility as a glazing element for an opening in any structure other than a building, in particular a vehicle, a vessel, an aircraft or the like, and the opening may be for the entry of daylight into the vehicle, vessel or aircraft, or for the transmission of light from a light source carried thereby.

Various embodiments of the present invention will now be more particularly described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view through a portion of a first embodiment of the invention illustrating the paths followed by certain rays of incident light;

Figure 2 is a cross-sectional view of the embodiment of Figure 1 illustrating the paths of rays of incident light arriving at a different angle of incidence;

Figure 3 is a cross-sectional view similar to that of Figure 1, of a second embodiment of the invention;

Figure 4 is a cross-sectional view through a third embodiment of the invention;

Figure 5 is a cross-sectional view through a fourth embodiment of the invention;

Figure 6 is a cross-sectional view through a further embodiment of the invention;

Figure 7 is a cross-section through a modified embodiment of the invention showing the paths of certain

rays through the embodiment; and

Figure 8 is a cross-section through the same embodiment as in Figure 7, but showing the paths of different incident light rays.

5

Referring now to Figure 1 the embodiment shown comprises a unitary transparent body generally indicated 11 by which enhanced daylighting performance is achieved by ensuring that a substantial proportion of the light  
10 incident from higher angles of elevation is reflected towards the ceiling of a room having an opening across which the optical component 11 is fitted. In this embodiment the optical component 11 is intended to be secured to the inner or exit face of a supporting pane of  
15 glass 15, although the glass itself has no influence on the diversion of light and it would be possible for embodiments of the invention to be produced in such a way that they are self-supporting.

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The optical component 11 comprises, as mentioned above, a single unitary transparent body 12 having an incident surface generally indicated 13 and an exit surface generally indicated 14, and in this embodiment the incident surface 13 is in contact with one face 15 of a  
25 supporting pane of glass shown in broken outline in Figure 1. Typically the thickness of the body 12 may be in the region of 1-1.5 mm, perhaps less, whilst a supporting pane of glass may be typically in the region

of 4 mm or more for which reason only the rear face 15 of the glass is shown.

5 The incident surface 13 is interrupted by a regular array of parallel elongate grooves 16 which are all identical or similar in form and the configuration of only one of which will therefore be described in detail. Between the grooves the surface 13 is defined by co-planar elementary faces identified by the reference numeral 17. Each  
10 groove 16 is defined by two opposite side walls 18, 19 inclined to one another, of which the side wall 18 is the downwardly facing upper side wall of the groove in the orientation shown, with the grooves 16 being substantially horizontal, the side wall 19 being the  
15 upwardly facing lower side wall of the groove 16.

Each groove 16 has a groove bottom 20 defined by two inclined groove bottom wall elements 21, 22 of which the groove bottom wall element 21 is an upwardly facing upper  
20 surface (in the orientation shown) and the groove bottom wall element 22 is a downwardly facing lower surface. The upper groove bottom wall element 21 is inclined so as to face outwardly as well as upwardly whilst the lower groove bottom wall element 22 is inclined so as to face  
25 outwardly as well as downwardly.

The two groove bottom wall elements 21, 22 meet at an apex 23 and the boundaries of the groove bottom 20 are

defined by the linear intersections of the respective groove upper side wall 18 with the adjacent upper bottom wall element 14 (to form an upper fundus 24) and the intersection between the groove lower side wall 19 with the lower bottom wall element 22 (to form a lower fundus 25). The two groove bottom wall elements 21, 22 meet at a reflex angle the corresponding internal angle of which is greater than the angle between the groove side wall and the groove bottom wall which meets it.

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In use of the optical component described above, with the component occupying a substantially vertical orientation, light incident on the elementary faces 17 or lands of the incident surface 13, at an angle of incidence less than a predetermined threshold angle, is transmitted directly through the component without deviation as shown in Figure 2 by the light rays A and B. The threshold angle lies above and below the horizontal plane which is normal to the elementary faces or lands 17 so as to encompass the majority of the field of view of interest to an observer within the room.

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As can be seen in Figure 1, light incident on the elementary faces 17 at an angle greater than the threshold angle, as represented by the light rays D and E of Figure 1, are refracted upon passage through the elementary incident surface 17 and reflected upon arrival at the upper side wall 18 of the immediately underlying

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groove 16. After reflection the light rays then travel through the body of the optical element and exit through the exit face 14 at a slight upward inclination.

- 5 Light above the threshold angle which falls on the element 12 between two elementary faces 17, that is light which enters a groove as shown by the light rays F, G and H in Figure 1, are first refracted at the interface defined by the lower side wall 19 of the groove and then
- 10 refracted again when they pass through the interface defined by the upper side wall of the next lower groove. Upon refraction the light is directed to the upper bottom wall face element 21 at which it is refracted and, thereby, diverted towards the lower bottom wall element
- 15 22 of the groove. At the interface defined by the lower bottom wall element the light is reflected, as shown in Figure 1, to pass through the body 12 of the element and out through the exit face 14 in an upwardly inclined orientation. The prisms at the bottom of each groove
- 20 therefore effectively "sweep up" any light entering the body 12 other than through the elementary faces 17, and which would in their absence be transmitted in a generally downwards direction upon passing through the exit face 14. Although not shown, it would be possible
- 25 to form these prisms with facets inclined to one another rather than the single face shown in Figure 1.

As can be seen in Figure 2, for an observer viewing the

outside through the element 11 and looking substantially horizontally, about 50% of the eye's viewing area admits light from the outside substantially undeviated, while most of the remainder of the viewing area contains light that originated inside the room. As the room is relatively dark compared with outside objects the view of the outside is substantially unaffected by light reflected back into the room, this light being of much less intensity than the transmitted light. Light rays, such as ray J which result from the reflection of light incident on the element 11 from within the building, is relatively less bright (or intense) and does not contribute much to the image seen by the eye.

Referring now to Figure 3, the general configuration of the optical element is generally the same as that in the embodiment of Figures 1 and 2, and accordingly the same reference numerals have been used to identify the same components or those which fulfil the same function. In this embodiment, however, the lower side wall 19 of each groove is substantially perpendicular to the plane defined by the elementary faces or lands 17 of the incident surface whilst the upper side wall of each groove has two elementary faces or facets, namely an "inner" facet 26 which, like the groove side wall 19 is orthogonal to the plane defined by the elementary faces 17 of the incident surfaces, and an inclined "outer" facet 27. The term "inner" as used herein to describe the

positions of groove side wall facets will be understood to mean facets located more deeply into the groove, while the term "outer" will be understood to refer to positions closer to the mouth of the groove. The light rays D and E, which upon refraction are incident on the "inner" groove face element 26 are reflected thereby as in the embodiment of Figures 1 and 2, although here the angle of reflection differs. The inclined "outer" facets in the upper side wall of the grooves make it possible favourably to "tune" the distribution of the reflected light. For example it will be appreciated that light from high in the sky generally falls further "outboard" (ie: towards the left as viewed in Figure 3) on the facets 26, 27 than the light arriving lower elevations. It is possible therefore to optimise the angle of the "outer" facet 27 to direct these higher elevation rays into the room at a desired angle.

By contrast with the embodiment of Figures 1 and 2, however, some of the light incident on the incident surface between adjacent surface elements 17, that is light entering the grooves 16, will fall on the lower side wall 19 of the groove. After refraction some of the rays, exemplified by rays F and G in Figure 3, impinge on the triangular prism constituted by the two groove bottom walls 20, 21 and are reflected upon arrival at the lower groove bottom wall 22 back to the upper groove bottom wall 21 where they are again reflected as illustrated in

Figure 3.

Some of the light, however, as exemplified by light ray H does not impinge on the triangular prism even after refraction at the interfaces 19 and 27, and is refracted again, at the interfaces 19 and 26 of the next lower groove. Then, being deeper into the body 12 of the optical element when arriving at the prism constituting the bottom of the next lower groove it is reflected in a manner as described above.

In the embodiment of Figure 4, where again corresponding components as indicated with the same reference numerals as in the embodiment of Figure 1, the groove upper and lower side walls 18, 19 are both planar and both perpendicular to the incident surface elements 17. The behaviour of this embodiment differs from that of Figure 1 inasmuch as the light, exemplified by ray K, exiting the room through the exit surface 14 and travelling through the body 12 towards the incident surface 17 is reflected five times before being returned to the room. Light from outside (the left of Figure 4) incident on those areas of the exit surface 14 in register with the elementary surfaces 17 will pass straight through, as exemplified by the light ray L.

The embodiment of Figure 5 is quite different from those of Figures 1 to 4 but operates on the same basic

principle. It provides an interface for sweeping up and reflecting incident light arriving between elementary surfaces 17, that is light which enters the grooves 16. In order to achieve this the side walls of the upper walls of the grooves 16 are formed, like the embodiment of Figure 3, as two elementary side wall facets comprising an inner upper groove side wall facet 26 and an outer upper groove side wall facet 27. The groove lower wall is composed of three facets inclined at shallow angles to one another and comprising an inner facet 28, an intermediate facet 29 and an outer facet 30. The effect of this is to orientate the reflecting interfaces appropriately to divert incoming light rays as exemplified by rays M, N, O, P of Figure 5.

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Figure 6 illustrates a further alternative embodiment in which, in place of the elementary faces or lands 17 of the incident surface 13 the bottom of each groove is formed as a flat elementary face 32. The groove side walls comprise a flat, inclined upwardly facing lower side wall 19 and a composite downwardly facing, upper side wall comprising inner upper wall facets 31, intermediate upper wall facets 32 and outer upper wall facets 33. The side walls or side wall facets defining adjacent grooves meet at an intersection line 134 such that adjacent grooves are effectively contiguous. Typical light ray paths for one angle of incidence are illustrated.

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Figures 7 and 8 illustrates an embodiment in which there are both flat incident surface facets 17 and flat groove bottom walls 32. The upwardly facing groove bottom wall 19 is flat and perpendicular to the incident face 17, and  
5 the downwardly facing groove upper wall is composed of three facets 31, 32, 33 like the embodiment of Figure 6. In this embodiment light at an angle above the horizontal less than a certain threshold value and incident on either the flat surface elements 17 or the flat groove  
10 bottoms 32 is transmitted through substantially undeviated to allow the external environment to be viewed from the inside.

On the other hand, light arriving from above this  
15 threshold angle and entering a groove 16 is refracted at the face 19 and then reflected at one of the facets 31, 32, 33 to be directed through the exit face at a slight rising inclination. Light arriving in any given direction at the interface defined by the upper groove  
20 wall facets 31, 32, 33 is reflected more steeply from the facet 31 nearer the groove bottom than from the facet 33 nearer the mouth of the groove so that for a given angle of incidence some of the light leaving the exit face 14 is directed in a steeper direction than the  
25 remainder of the light arriving at this angle of incidence.

This provision of several facets also serves to ensure

that incident rays from a relatively wide range of high angles above the horizontal is transmitted through the element to exit within a relatively narrow range of relatively low angles above the horizontal. This is illustrated in Figure 8 in which three incident light rays Q, R and S at successively smaller angles of incidence are shown. As will be seen, because of the relative inclination of the facets 31, 32 and 33 the emerging light rays are all generally parallel to one another and all inclined upwardly at a shallow angle which encourages good penetration to the back of the room furthest from the opening.

All of the optical elements described herein may be self-supporting or may be formed as films to be faced on to a transparent support such as a window pane. Such support is preferably provided on the incident face, namely to the left of the element as shown in the drawings, and this may be the outer layer of a double glazing cell. This has the advantage of isolating the grooves, which may be very fine features, from dust and other atmospheric contaminants. The dimensions of the grooves may typically be from to in width and from to in depth. Although described as a unitary element it will be understood that the invention may be put into practice as a composite element made up from a plurality of parts, as long as the faces and interfaces have or provide the same relationships.

## CLAIMS

1. An optical element comprising a transparent body having two substantially parallel major faces one of which is interrupted with a plurality of cavities defining a plurality of interfaces at which light incident thereon over a certain range of angles is reflected by total internal reflection, characterised in that at least some of the light incident on the said body is substantially undeviated in its transmission through the body, in that the said one face of the element in which the cavities are formed is intended in use to face a source of light, and in that the width of the cavities is such that at least a substantial proportion of the light incident on the said one face enters the said cavities.

2. An optical element as claimed in Claim 1, in which the cavities are formed as elongate grooves in the said one face of the body.

3. An optical element as claimed in Claim 2, in which the elongate grooves constituting the said cavities are defined by at least two side walls and the maximum groove width, namely the maximum separation between the groove walls is not less than the separation between adjacent grooves.

4. An optical element as claimed in any of Claims 1 to 3, in which the surrounding medium is air.

5. An optical component as claimed in any preceding claim, in which the said body is a unitary element of flexible material adapted to be supported on a face of a substantially planar transparent support element.

6. An optical element as claimed in any of Claims 1 to 4, in which the said body is composed of a plurality of juxtaposed or connected elementary parts.

7. An optical element as claimed in any preceding claim, in which at least one of the walls of at least some of the cavities is formed as a curved surface.

8. An optical element as claimed in any preceding claim, in which at least one of the walls of at least some of the cavities is composed of at least two substantially planar wall elements or facets inclined at a non-zero angle to one another.

9. An optical element as claimed in any of Claims 2 to 8, in which at least some of the elongate grooves in the said one face of the body have a groove bottom constituted by the intersection of the groove side wall elements, or by the intersection of a groove side wall element with a groove side wall.

10. An optical element as claimed in any of Claims 2 to 8, in which at least some of the elongate grooves in the said body have a bottom wall defined by two surfaces inclined to one another at a reflex angle.

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11. An optical element as claimed in Claim 10, in which the included angle at which the said two bottom wall surfaces meet is greater than the angle between the two groove walls or the wall surface elements or facets adjacent the groove bottom.

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12. An optical element as claimed in any of Claims 2 to 8, in which at least some of the elongate grooves in the said one face of the body have a substantially flat bottom substantially parallel to the other said major face.

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13. An optical element as claimed in Claim 12, in which adjacent grooves are contiguous.

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14. An optical element as claimed in any of Claims 2 to 13, in which the pitch of the grooves is of the same order of magnitude as the depth of the grooves.

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15. An optical element as claimed in any of Claims 2 to 14, in which the depth of the grooves is of the order of, or less than 1 mm.

16. An optical element as claimed in any preceding claim, in which the depth of the cavities is in the region of half the thickness of the element between the major faces.

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17. An optical element as claimed in any preceding claim, in which the shape of the cavities is such that light entering a cavity is refracted at the cavity side wall towards a next adjacent cavity and light thus arriving at the side wall of the said next adjacent cavity is reflected by total internal reflection.

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18. An optical element as claimed in Claim 17, in which the side walls of the cavities are so formed as to define a plurality of side wall facets at each of which a proportion of the refracted light is deflected so as to be below the threshold angle for the next adjacent surface element in the path of the incident light.

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19. An optical element as claimed in Claim 17 or Claim 18, in which the side wall facets of substantially parallel grooves in the said one face of the element extend generally horizontally when the element is in its intended position of use, and those facets defining generally downwardly facing surfaces of the grooves are inclined to one another at shallow angles such that each said downwardly facing groove-defining surface is downwardly convex.

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20. A glazing assembly for an opening in a body, such as a building, a vehicle, a vessel or an aircraft, comprising a substantially rigid panel of transparent material having an optical element as claimed in any preceding claim affixed thereto by a substantially transparent cement or bonding agent.

21. A glazing assembly according to Claim 20, in which the said one face of the optical element is orientated towards the said support panel.

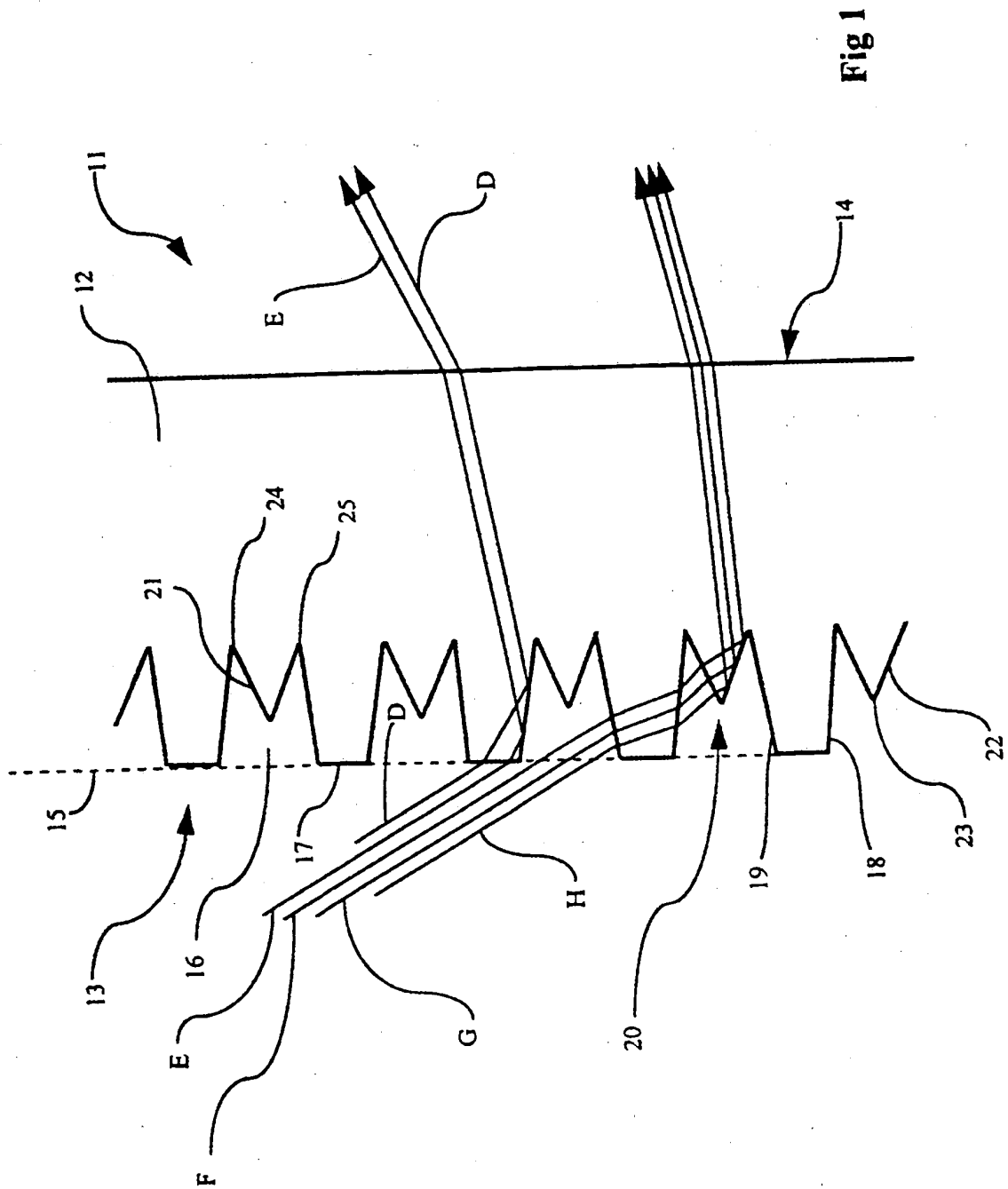
22. A glazing assembly according to Claim 20, in which the said one face of the optical element is oriented away from the said support panel.

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23. A glazing assembly according to Claim 22, in which the said support panel is one of two substantially parallel panels of a double glazing cell and the said one face of the optical element faces towards the other of the said panel of the cell.

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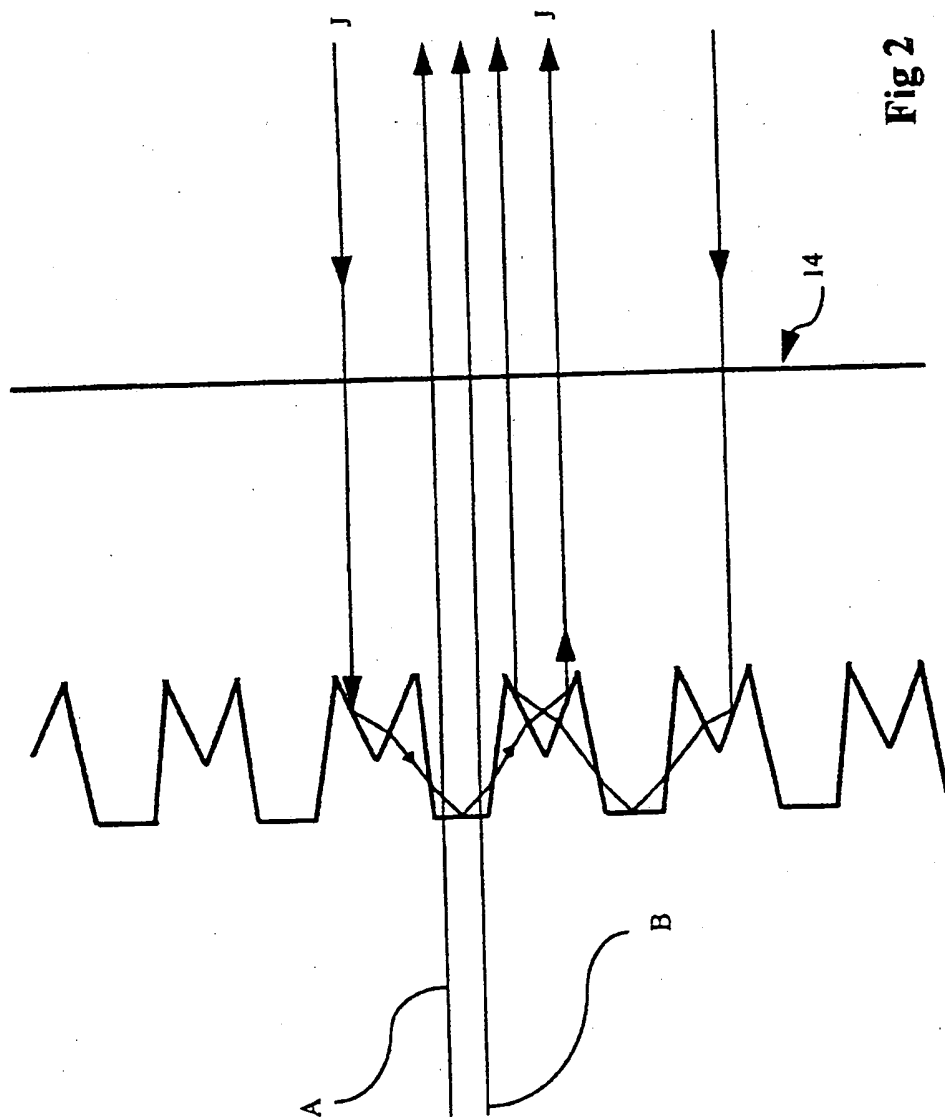
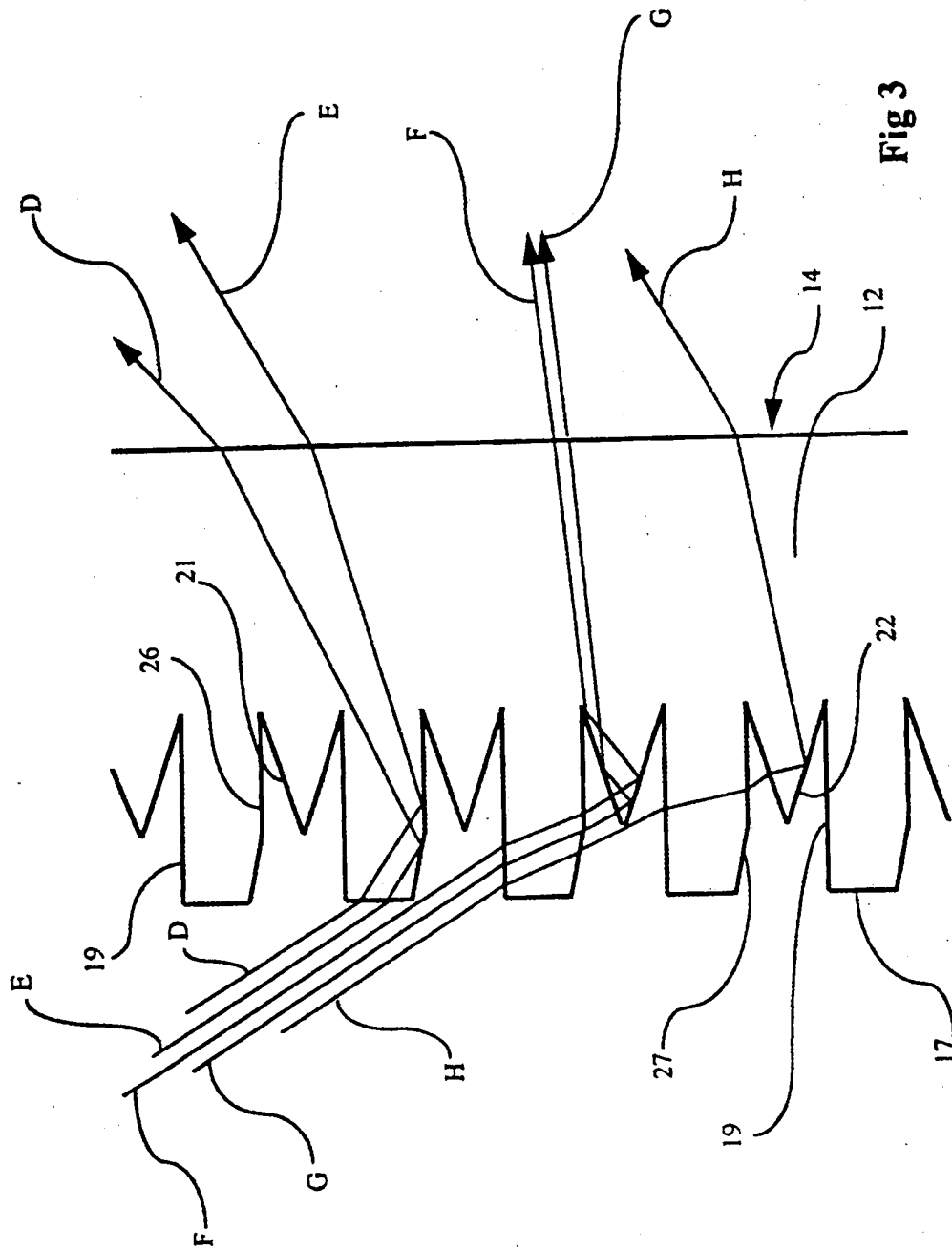


Fig 2

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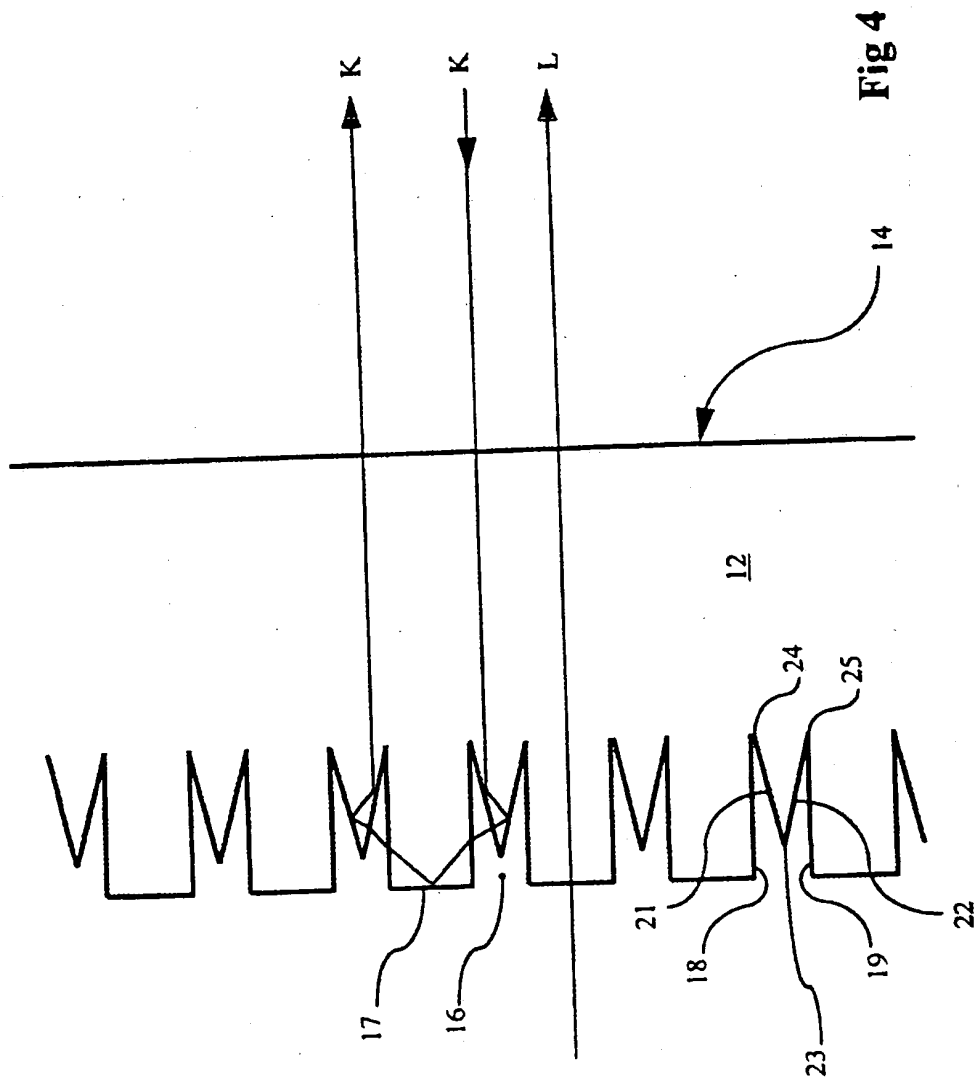
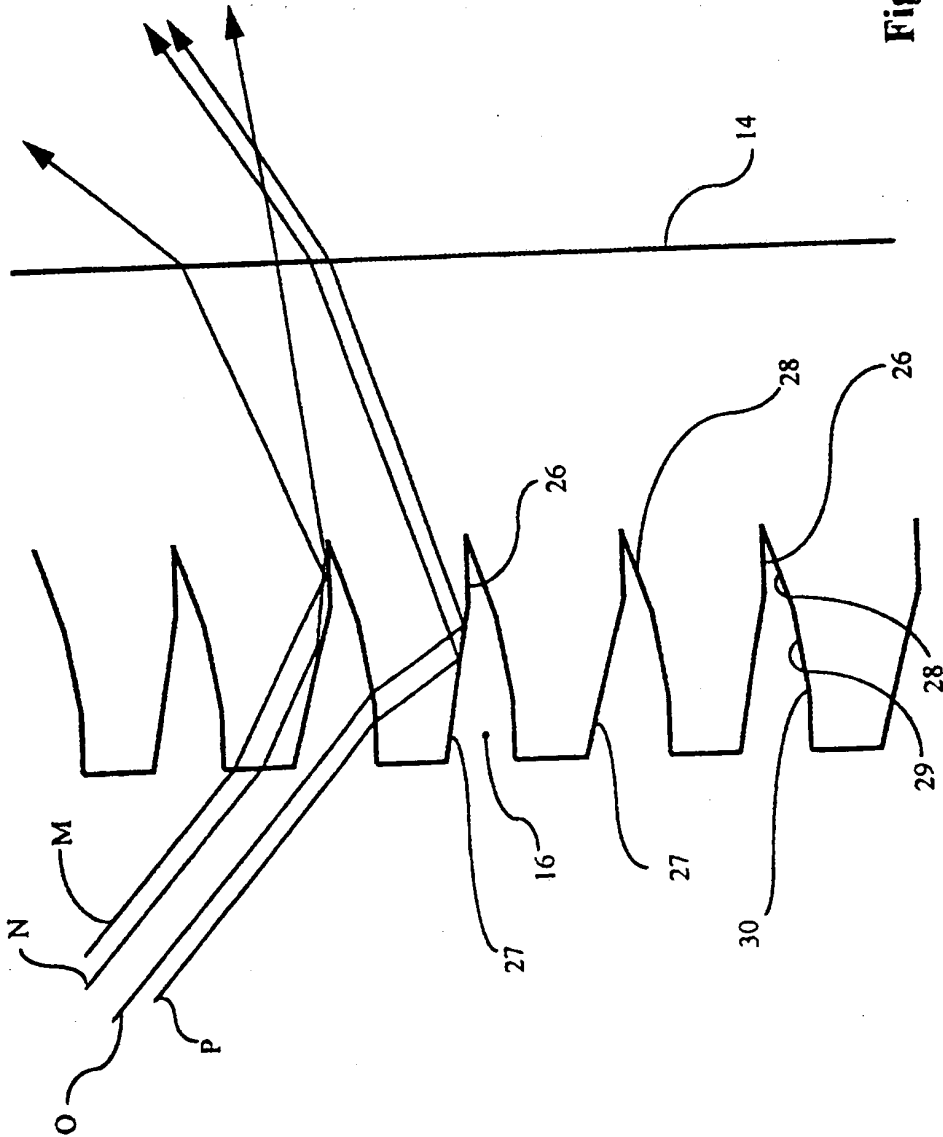
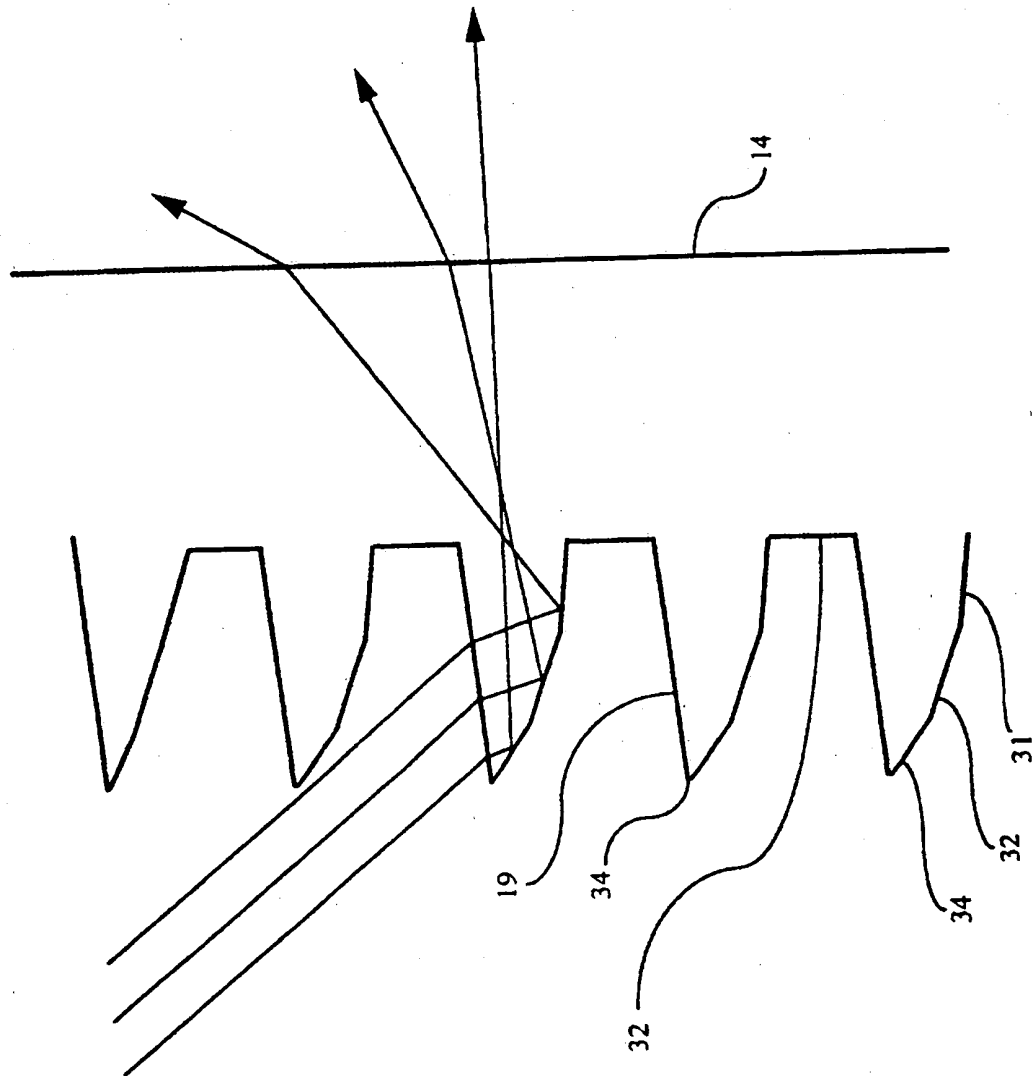


Fig 4



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Fig 6



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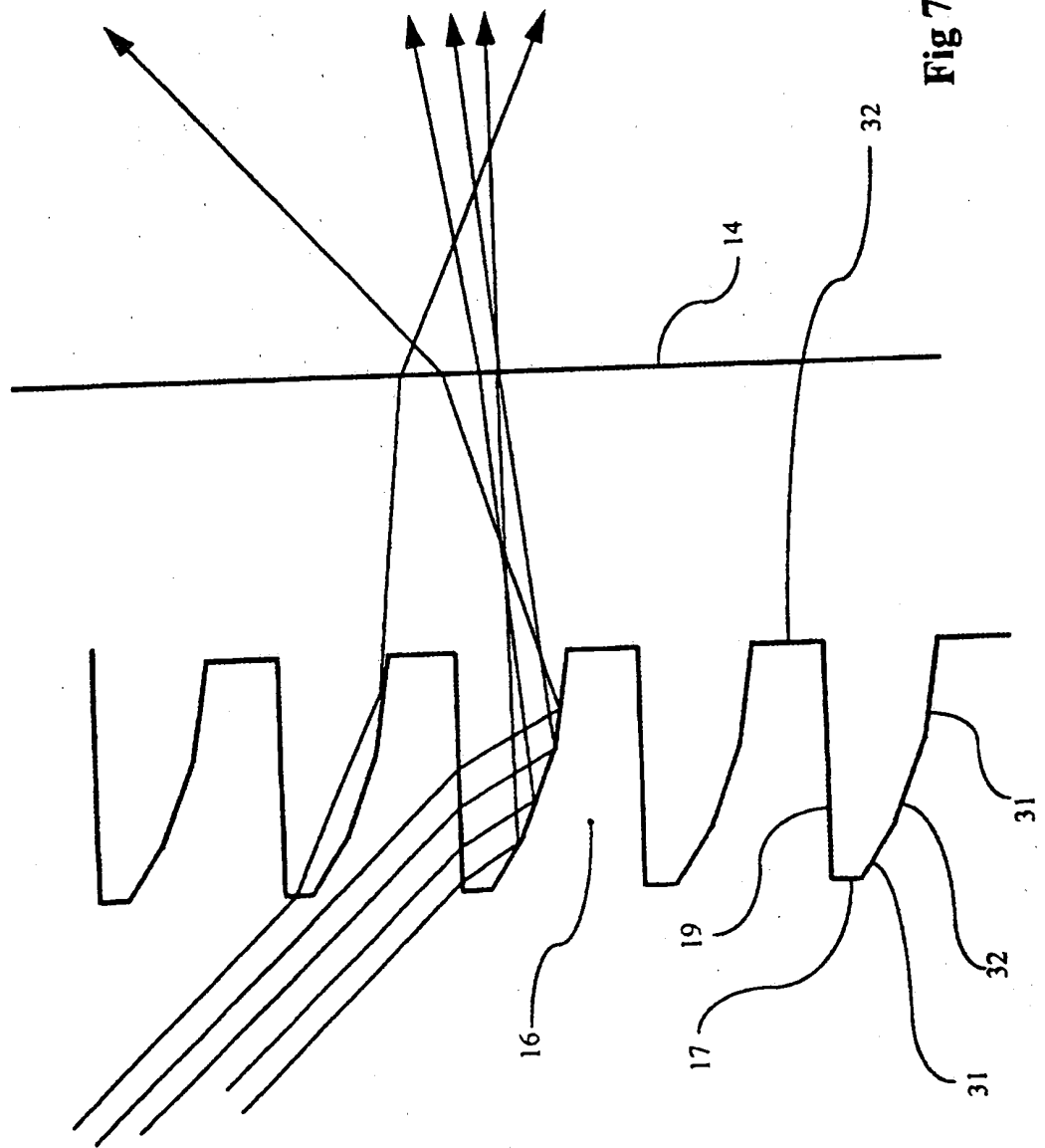
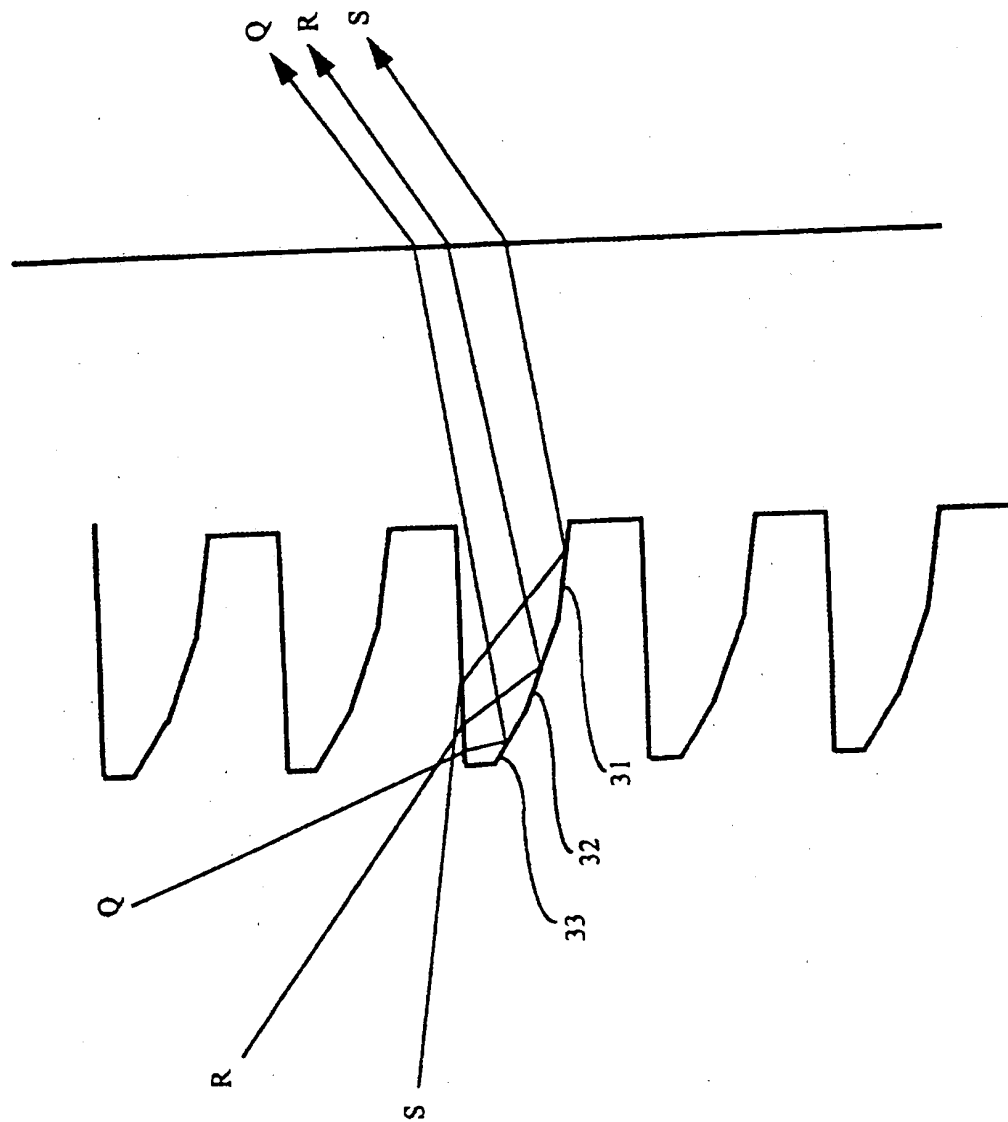


Fig 7

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Fig 8



# INTERNATIONAL SEARCH REPORT

Int. Application No  
PCT/GB 97/00517

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 G02B5/00 F21S11/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 G02B F21S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 989 952 A (EDMONDS IAN R) 5 February 1991 cited in the application see column 3, line 1 - column 4, line 51; figures 1-7 ---	1-6, 20-23
A	WO 94 25792 A (MILNER PETER J) 10 November 1994 see page 13, line 23 - page 30, line 9; figures 1-16 ---	1-8, 16-23
A	WO 91 03682 A (UNIV QUEENSLAND) 21 March 1991 cited in the application see page 10, line 33 - page 12, line 33 see page 14, line 11 - line 33; figures 1-8, 15-19 --- -/-	1-8, 12, 13, 17-23

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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1.

Date of the actual completion of the international search

2 June 1997

Date of mailing of the international search report

13.06.97

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# INTERNATIONAL SEARCH REPORT

Int .onal Application No  
PCT/GB 97/00517

C:(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 557 565 A (RUCK NANCY C ET AL) 10 December 1985 see column 3, line 1 - column 4, line 3 see column 4, line 37 - column 5, line 43; figures 1-5,9 ---	1-6, 14-23
A	US 4 411 493 A (MILLER JACK V) 25 October 1983 see column 1, line 35 - column 2, line 5 see column 3, line 3 - column 4, line 15; figures 3-7 -----	1-13, 17-23

# INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. Application No  
PCT/GB 97/00517

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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WO 9103682 A	21-03-91	AU 641429 B AU 6348190 A CA 2066412 A EP 0493419 A US 5295051 A	23-09-93 08-04-91 09-03-91 08-07-92 15-03-94
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US 4411493 A	25-10-83	NONE	